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Applying event related potentials to evaluate user preferences toward smartphone form design

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ABSTRACT

Product forms can affect user preference and play an important role in user's purchasing decisions. Neuroimaging methods can provide an improved understanding of the mechanisms of decision making, which enhance the ability of enterprises to effectively design their products. Hence event related potentials (ERPs) were applied to explore the brain activity evoked by variety of product forms when users made preference among them. Smartphone product forms were displayed with equiprobability randomly. Participants were asked to click the left mouse button when they preferred one product form, else the right button for nonpreferred. The brain signals of each participant were recorded by Curry 7.0. Finally, brain signals were processed by using Curry 7.0 SBA and SPSS 18.0 software. The results showed that preferred product forms evoked enhanced N2, P2 and P3. Moreover, there were significant correlation between ERPs and behavioural data, participants devoted more attention and had faster responding time to preferred products than to nonpreferred. These results indicate that the differences of ERPs can be used to evaluate user preference.

Relevance to industry: The integration of customer preferences is nowadays a challenge in new product development. Hence a thorough research on the inherent mechanism of preference formation can provide an accurate measurement method of user's perception. The differences of brain signals evoked by product forms can also provide technical support for product designers, which in turn can meet with user experience. Moreover, the results can be taken as evaluating indicators of product design.

1. Introduction

User's decision to use a product is motivated not only by its functional competence, but also positive experience by its physical appearance (Yadav et al., 2013; Wu et al., 2014). The product appearance plays an important role in users' preference and purchase (Chuang et al., 2001; Lin et al., 2007; Ming et al., 2001). This is largely because that “what the product looks like” before purchasing is more important than product price in policy-making (Ho and Lu, 2014; Borsci et al., 2016). As Norman (2004) pointed out that, only if a product catch user's first sight or attention will “what is it?” and then “how much is it” happen. Moreover, sales platforms such as the Internet cannot provide users real interaction but visual perception of product appearance alone (Diego-Mas and Alcaide-Marzal, 2016). It is reasonable to assume that consumer preference for a product is mainly based on the form features (Shieh and Yang, 2008; Ming et al., 2001). Hence, it is crucial for designers and marketers to capture and characterize user preference of product form. And user preference measurement has received much attention in both academia and industry.

The affective aspects, potential and intuitive feelings contained in user preference bring challenges for evaluation. Traditionally, subjective methods are mostly used for user preference measurement, such as emotional questionnaire (Agost and Vergara, 2014), fuzzy decision support system (Alptekin, 2012; Hsiao and Ko, 2013), semantic differential and Kano's model in Kansei engineering (Llinares and Page, 2011) and so on. However, these methods have limitations for the assumption that people are actually able to describe their cognitive process without considering users' affective and intuitional responses (Ariely and Berns, 2010; Calvert and Brammer, 2012; Ding et al., 2016). These methods are underpowered to measure user preference accurately. With the characters of subjective, involving emotion, dynamic and often formed intuitively without explicit reasoning (Chuang et al., 2001; Bhushan et al., 2012; Agost and Vergara, 2014), more accurate methods are

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needed to measure user preference.

Based on this motivation, several studies measured preferences for products using physiological and neural responses (Ohira and Hirao, 2015; Khushaba et al., 2013; Javor et al., 2013). Wang and Minor (2008) summarized the validity, reliability and applicability of physiological techniques in marketing research, including eye movement, heart rate, blood pressure, facial muscle activity, voice pitch analysis and brain imaging. These methods collecting data from physiological aspects can give consecutive and real-time information produced by organs and accompanied by emotions (Bailenson et al., 2008; Ding et al., 2016). Among those indexes, brain responses can provide information not obtainable via conventional marketing research methods (e.g., interviews, questionnaires, focus groups) (Ariely and Berns, 2010). For evaluation of product preference, physiological indexes such as neuroimaging methods should have potential for measuring affective factors. In such cases, the effectiveness of product form design may be evaluated by monitoring people's brain activity resulting from observing different products. However, there is a substantial lack of research studying the neural mechanism of preference aroused by product forms (Céline, 2013).

In this challenging context, brain imaging has offered promising methodological alternative. There are several techniques for collecting brain activity data, in which event related potentials (ERPs) and functional magnetic resonance imaging (fMRI) are the most used methods (Sylcott et al., 2013; Daliri, 2013). In fMRI, hemodynamic responses reflect the perception and cognition of object presented, and are used to predict user preference (Kenning and Plassmann, 2008; Van der Laan et al., 2012). The previous studies revealed that the signals related to user preference of a single object from different brain areas have overlaps (McClure et al., 2004; Sylcott et al. (2013); Hampton et al., 2007; Van der Laan et al., 2012). These fMRI studies on preference tended researchers to use ERPs for user preference.

Compared to fMRI, ERPs is more appropriate for brain data collection for lower cost of experiment design and at very high temporal resolution (even to 10,000 times per second) (Plassmann et al., 2007; Morin, 2011; Daliri, 2013). In the experiment, electrodes are placed on the scalp of a participant by using an electroencephalograph (EEG) cap. Then ERPs can be obtained through subsequent processing which can reflect people's psychological activities (Luck, 2014). An ERP waveform is labelled by the polarity (Positive or Negative), latency and distribution over the scalp (Daliri, 2013). “ERPs reflect brain activity from synchronously active populations of neurons that occurs in preparation for or in response to discrete events, be they internal or external to the subject.”(Fabiani et al., 2000).

With the development of ERPs, they are regarded as neural manifestations of specific psychological functions (Fabiani et al., 2000; Treleaven-Hassard et al., 2010; Luck, 2014). Handy et al. (2010) pointed out that earlier P2 (peaking around 200 ms post-stimulus) and the late positive potential (beginning around 400 ms poststimulus) are sensitive to emotional stimulus and can reflect whether participants like a logo. Herbert et al. (2006) pointed out that P2 and P3 potentials are larger for both positive and negative valence stimuli relative to a neutral valence baseline. While in the study of Wang et al. (2012), larger P2 amplitudes are evoked when participants browse beautiful pendants than ugly in frontal, central and parietal lobes. In the process of subjective evaluation, negative stimuli can elicit smaller P2 amplitudes (Yuan et al., 2007). Lindsen et al. (2010) found that larger late positive potentials are evoked by attractive faces compared to less attractive. Patel and Azzam (2005) reviewed studies about N2 and P3, which appear to be closely associated with the cognitive process of perception and selective attention.

From the above studies, the explanations of neuroimaging data are varied with the differences of stimuli, experimental paradigm or subjects (Solnais et al., 2013). And this method might infringe personal privacy to a totally unacceptable degree (Lee et al., 2007). But a lot of researches investigated the changes in brain activity while participants observe brand, products or TV advertising (Ma et al., 2010; Khushaba et al., 2013; Handy et al., 2010; Treleaven-Hassard et al., 2010). However, previous studies of affective evaluations have predominately relied on using stimuli (e.g. faces, pictures and words) which were deliberately selected for having strong emotional valence (Handy et al., 2010). Hence, what about daily products, what kind of visual products can engender a sense of good feeling or user preference? How product forms affect people's neural responses is still unclear (Céline, 2013).

With the narrow differences between smartphone forms, users cannot totally describe why they prefer one than others. Hence, based on previous studies in neuroscience and preference, ERPs was applied to investigate user's brain responses when they made preference among several product forms. In the experiment, smartphones forms were designed according to popular products mainly different with each other in screen size, colour and edges and corners. Then six smartphone forms were screen out preliminarily according to the whole visual experience. And these six smartphones were selected as stimuli in the ERPs experiment to analyse the neural activities during assessing user preference. And hypothesis was made that product form judged as preference could yield different neural activity for several ERPs components compared to nonpreferred as well as behavioural level.

2. Research method

2.1. Participants

Fourteen healthy right-handed students (7 males, range 24–32 years, mean age 25.4 years, SD = 2.13) from Northeastern University majoring in management science and engineering with a background of ergonomic were recruited as participants. They were all with normal or corrected-to-normal vision and without history of neurological or psychiatric disorders. They all signed written consent forms to participate before the experiment and received a gift worth about 5 $ as compensation.

2.2. Stimuli

By analysing the form features affected user's visual experience of smartphone, screen size, colour and edges and corners are the key indexes (Yun et al., 2003; Tsai and Ho, 2013). According to these features, several stimuli were designed by Pro/ENGINEER Wildfire 5.0 (PTC) software. Finally six smart phone pictures with difference in the whole feeling were selected, the subjective evaluation is based on the method of Guo et al. (2016). The size of pictures is set to 700 × 460 pixel, which made the smart phones more realistic-looking. The pictures are browsed with the same angle. Fig. 1 gives the details of each stimulus and all of the stimuli have the same thickness (8.7 mm).

2.3. Procedure

Participants sat in front of a computer screen comfortably in a quiet room with soft light and they were asked to focus on the central of the screen. The participants viewed the stimuli from a distance of 70 cm and had a visual angel of 11.4° × 5.9°. The task was programmed and presented by using E-Prime professional (vision2.0, Psychology Software Tools). Stimuli were displayed randomly, and manual responses to the target were made by

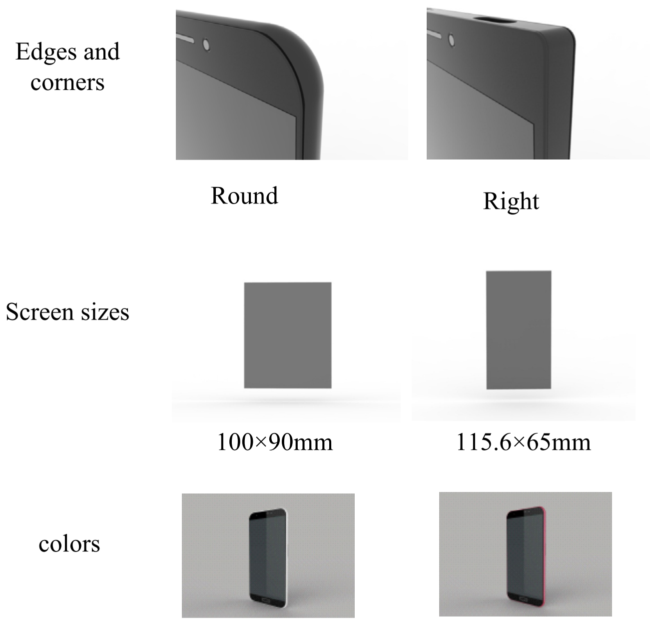

Fig. 1. The details of three pairs of stimuli.

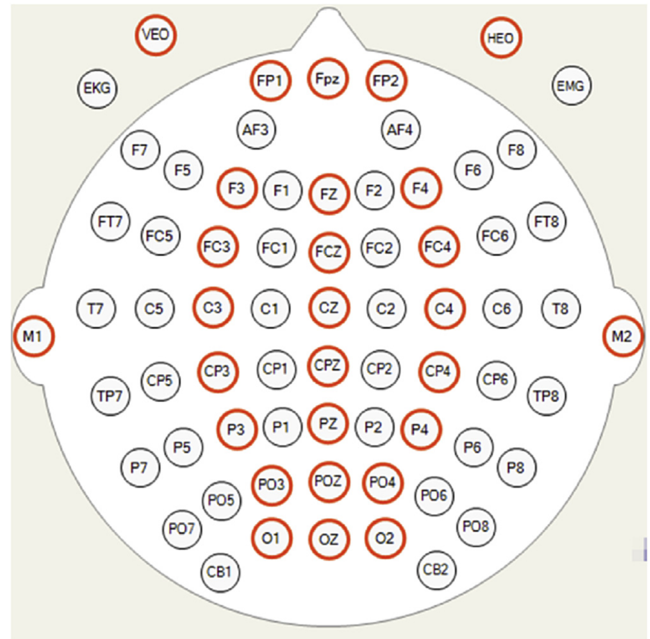

Fig. 3. The electrodes sites (red) used in experiment. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

pressing the left mouse button when a smart phone picture is preferred, else the right button. Each picture will repeat 40 times, and the steps of experiment are show as Fig. 2. The representation time of smart phone pictures is 1000 ms, and 1200–1500 ms for blank screen. There are four times of rest. The entire experiment lasted about 40 min, including electrode placement and instructions.

2.4. Electrophysiological recording and analysis

The EEG signals were continuously recorded by Neuroscan system (Neurosoft Labs Inc) with 24 Ag/AgCl electrodes (Fig. 3), which were selected according to the studies of Righi et al. (2014), Wang et al. (2012) and Handy et al. (2010). The electrode sites were based on an expanded version of the international 10–20 electrode placement system. A reference electrode was placed on the left mastoid with the midpoint of FPZ and FZ sites as the ground, at the same time the right mastoid was recorded. Vertical and horizontal electro-oculographic (EOG) activities were recorded with additional electrodes located 1.5 cm above and below the left eye and 1.5 cm outside the outer canthi of both eyes. All EEG electrode impedances were maintained below 5 kΩ. The EEG signals were filtered with a band pass of 0.05–100 Hz and digitized at a rate of 1000 Hz through Curry 7.0 (Neurosoft Labs Inc).

Offline data was processed by using Curry 7.0 SBA software (Neurosoft Labs Inc) and bilateral average of mastoids was used (Luck, 2014). EEG signals were computed by using EEG epochs that started from 200 ms before stimuli onset to 800 ms after stimuli onset. Moreover, each epoch was baseline corrected by using the signal during 200 ms that preceded the onset of the stimulus. Eye movement artifacts and epochs with amplitude greater than 75 μV were automatically rejected. ERPs were then averaged separately for each site and condition (preferred or nonpreferred), and filtered with a low-pass of 1–30 Hz. The ERPs analyses were conducted on the mean amplitude values for specific sets of electrode sites within predefined time windows. The single-subject ERPs were then used to derive the grand averaged waveforms for display and analysis. The principle of ERPs recording and analysing is showed as Fig. 4.

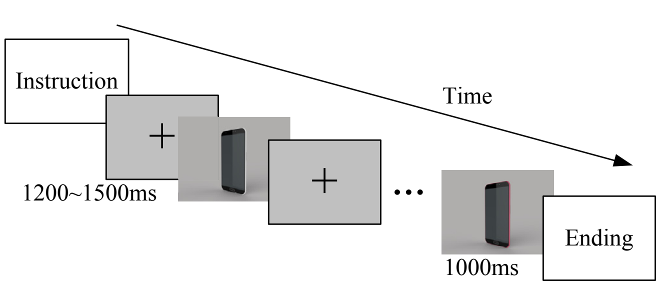

Fig. 2. The experiment procedure.

3. Results

3.1. Behaviour

Response time was recorded from onset of the smartphone picture on which preference was made. The smartphones were presented on the monitor and participants had to press the left button for preferred and right for nonpreferred. The average response time of non-preferred and preferred are 651.6 (SD = 53.08) and 619.9 (SD = 61.02), the two-sample paired *t*-test shows that the response time for preferred product is faster than nonpreferred with $t(13) = 2.71$, $p = 0 = 0.018$.

3.2. ERPs results

Grand averaged ERPs waveforms for preferred and nonpreferred are showed in Figs. 5 and 6 and topogranphic maps for each time window are showed as Fig. 7. ERPs analyses were conducted on mean amplitude values by using within-subject repeated-measures ANOVAs with Condition at two levels (preferred and nonpreferred) and Site at different levels. The sites vary depending on the analysed component. According to the related studies on attention

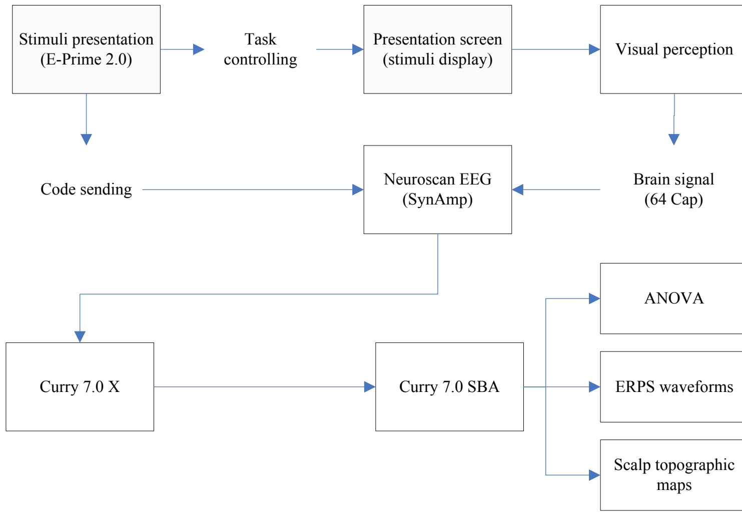

Fig. 4. The principle of ERPs (Ding et al., 2016).

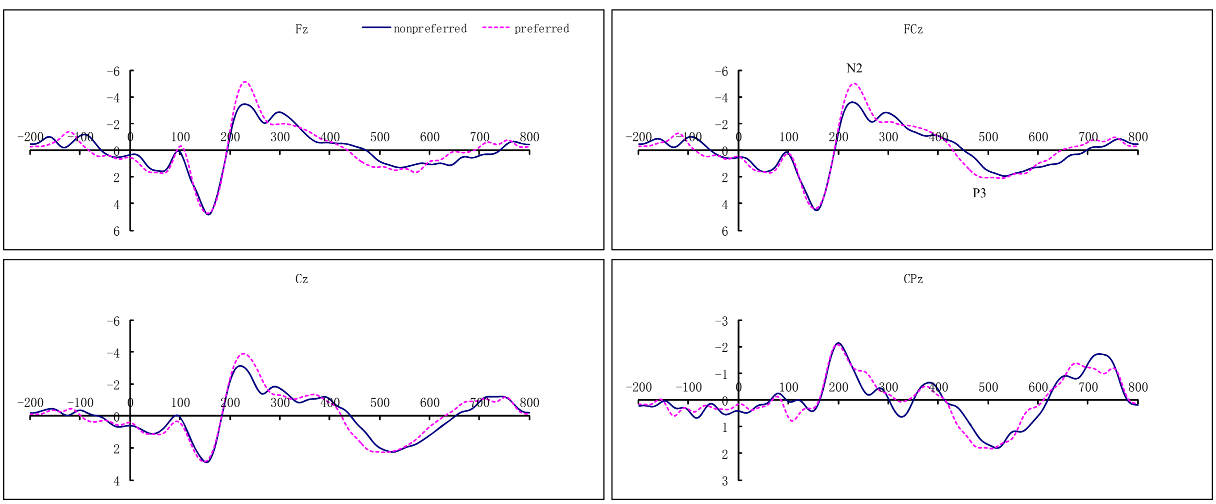

Fig. 5. The grand averaged ERPs evoked by preferred and nonpreferred stimulus for frontal, central, fronto-central and centro-parietal sites.

allocation (Polich, 2007), emotion (Wang et al., 2012), like/dislike (Handy et al., 2010), attractiveness (Righi et al., 2014), ERPs waveforms (Figs. 5 and 6) and topographic maps (Fig. 7), N2, P2 and P3 components are chosen to measure preference. Three electrode sites (Fz, FCz, Cz) are chosen for statistical analysis for N2 and parietal, parieto-occipital and occipital electrode clusters (P3/4, PO3/4, O1/2) are chosen for statistical analysis within the time window of 200–260 ms for P2, and four electrode sites (Fz, FCz, Cz, CPz) are chosen for statistical analysis within the time window of 420–600 ms for P3.

In order to correct the violations of the Sphericity assumption, Greenhouse-Geisser correction was applied as well as the effect size (eta squared η^2) reported for all ANOVAs. An alpha level of 0.05 was used for statistical tests. Mauchly's tests indicated that the assumptions of sphericity were violated with ($W = 0.419$, $p < 0.01$ for N2; $W = 0.085$, $p < 0.001$ for P3; $W = 0.314$, $p < 0.05$ for the latency of P3). Therefore G-G correction was used.

There was significant main effect of condition with $F(1,13) = 14.107$, $p = 0.002$, $\eta^2 = 0.520$, but without interactions between condition and sites with $F(1.265,16.442) = 1.377$, $p = 0.270$, $\eta^2 = 0.096$ or sites with $F(1.161,15.095) = 3.538$, $p = 0.075$, $\eta^2 = 0.214$ for N2 (peaking around 230 ms) within time window of 200–260 ms. The results showed more negative N2 in the condition of preferred products.

There was main effect of condition on parietal, parieto-occipital and occipital with $F(1,13) = 16.472$, $p = 0.001$, $\eta^2 = 0.559$, without interactions between condition and sites with $F(2,26) = 3.026$, $p = 0.081$, $\eta^2 = 0.189$, or sites with $F(2,26) = 3.591$, $p = 0.060$, $\eta^2 = 0.216$ for P2 (peaking around 225 ms) with time window of 200–260 ms. The results showed larger P2 in the condition of preferred products.

The results of ANOVA showed that there was no interactions between condition and sites [$F(1.669,21.701) = 1.043$, $p = 0.357$, $\eta^2 = 0.074$]. There was main effect for condition with $F(1,13) = 5.836$, $p = 0.031$, $\eta^2 = 0.310$, and showed more positive P3 was elicited under the condition of preferred within time window of 420–600 ms. There was also main effect of sites with $F(1.307,16.991) = 13.081$, $p = 0.001$, $\eta^2 = 0.502$. The post-hoc analyses revealed that smaller P3 evoked at Fz than other sites ($ps < 0.05$) and larger P3 evoked at Cz than FCz ($p < 0.05$).

The results of ANOVA showed that there was no main effect of condition for the latency of P3 with [$F(1,13) = 4.036$, $p = 0.066$,

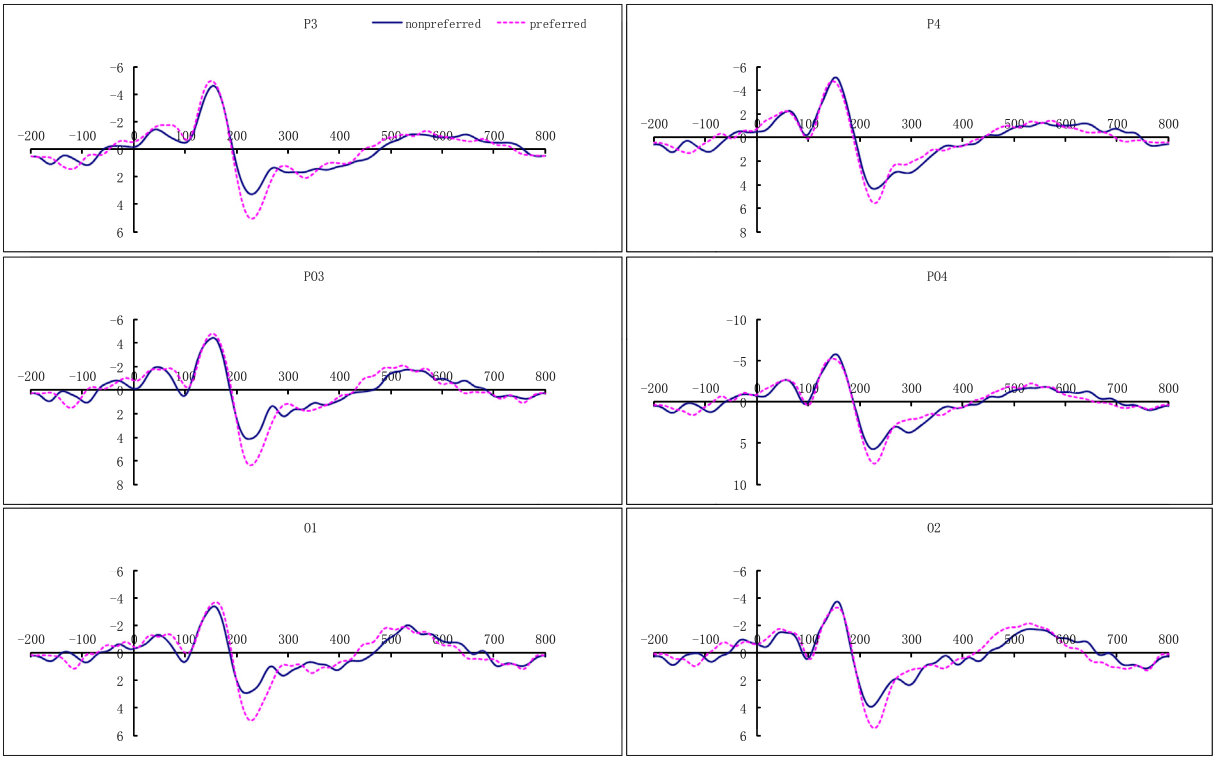

Fig. 6. The grand averaged ERPs evoked by preferred and nonpreferred stimulus for parietal, parieto-occipital and occipital sites.

$\eta^2 = 0.237$, only close to significant], or interaction between condition [$F(1.791,23.280) = 0.564$, $p = 0.558$, $\eta^2 = 0.042$] but sites [$F(1.512,19.658) = 7.328$, $p = 0.007$, $\eta^2 = 0.360$]. The post-hoc analyses revealed that the latency of Fz were larger than Cz and CPz ($p < 0.05$). The two-sample paired *t*-test in two conditions showed that the latency of P3 under preferred was significantly shorter than nonpreferred at FCz ($p = 0.037$) and CPz ($p = 0.011$).

Mean amplitudes across scalp sites and conditions are reported in Table 1 with two-sample paired *t*-test. The results showed that mean amplitudes of N2, P2 and P3 evoked by preferred smartphones were larger than nonpreferred. Consistent with the outcomes of statistics (Table 1), the results of Fig. 6 showed that the peak potential of N2 and P3 were distributed on the frontal and central scalp areas, and they were stronger in frontal-central areas in the condition of preferred; the peaks potential of P2 were distributed on the parietal, parieto-occipital and occipital scalp areas and they were stronger in the condition of preferred.

3.3. *Correlation analysis between behaviour and ERPs*

Table 2 shows the correlations (Pearson coefficient) between behaviour data and ERPs. There was significant negative correlation between the response time with the average amplitude of P3 ($r = -0.383$, $p = 0.044$), and positive correlation with the latency of P3 ($r = 0.394$, $p = 0.038$). There was no significant correlation between the response time with the average amplitudes of N2 or P2. The correlations between the average amplitude of N2 with P2 and between N2 with P3 showed significantly negative, but without significant correlation between the average amplitudes of P2 and P3 (close to significant, $p = 0.055$), or between the average amplitudes with the latency of P3.

4. Discussion

ERPs technique was used to explore the neural activities of the user preference evoked by visually presented smart phone pictures. The results highlighted that there were significant differences for preferred smartphone pictures both in several ERPs components and behavioural responses compared to nonpreferred.

First, consistent with previous literature (Chen and Bargh, 1999; Bamford et al., 2015), participants responded faster to preferred product forms than nonpreferred. Chen and Bargh (1999) and Bamford et al. (2015) pointed out that the automatic predisposition in cognition will drive people to approach pleasant and avoid unpleasant stimuli; the result is faster response to stimuli which can elicit pleasure feelings. In this view, preferred smartphone forms gave participants pleasure feelings so faster responses occurred.

Second, on the neural level, our results found that if a product form was liked by participants, then enhanced N2 would be evoked in anterior cortical (Figs. 5 and 7 and Table 1). N2 is related to automatic stimulus identification and appears to be closely associated with cognitive processes of perception and selective attention (Patel and Azzam, 2005). In this sense, as the task was required to find out the product forms participants preferred, with this task in mind more attention was devoted to the product form they preferred. The preferred product form could elicit participants' attention, positive feelings or affection to choose the one and this product form might meet with their preference better. Moreover, preferred product forms could attract participants' interesting and were impressive, so they could be remembered easily than nonpreferred ones, and this memory attention was reflected in enhance anterior N2 (Vogel and Machizawa, 2004). Construed from an emotional perspective, our findings are also consistent with the study of Carretié et al. (2004). In their study, pleasant stimulus elicited enhanced N2. Preferred product forms might give participants a pleasure feeling, so the same result was obtain in our study.

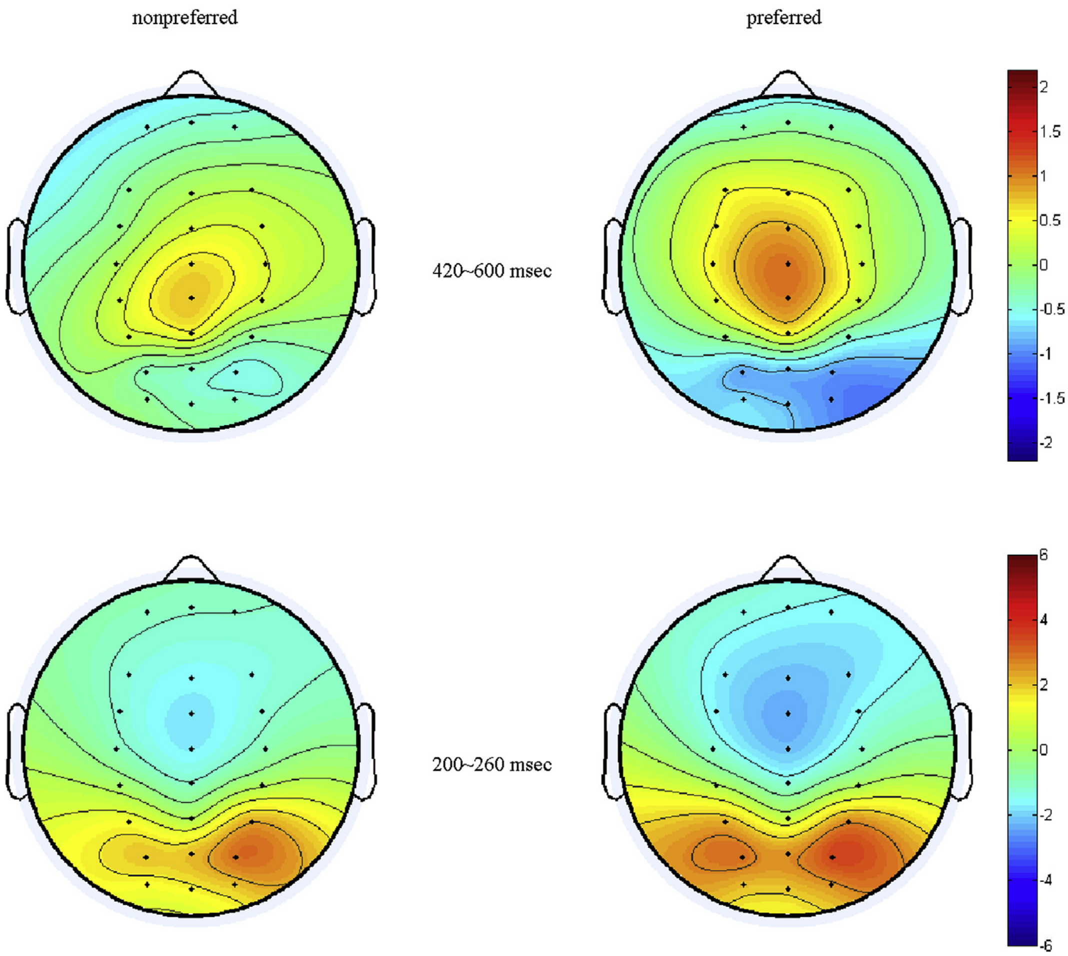

Fig. 7. The topographic maps of two conditions.

Table 1
Mean amplitude (μv) of group-averaged ERPs and the results of a two-sample paired *t*-test in two conditions at different sites.

ERPs	Sites	Nonpreferred		Preferred		t	p
		Mean	SD	Mean	SD		
N2	Fz	−4.10	1.89	−5.52	2.06	3.184	0.007
	FCz	−4.27	1.78	−5.53	1.91	3.396	0.005
	Cz	−3.85	1.60	−4.68	1.99	2.776	0.016
P2	P3	4.11	2.27	5.36	2.93	−3.328	0.005
	P4	5.26	2.57	5.86	2.89	−2.944	0.011
	PO3	5.13	2.39	6.93	3.04	−4.078	0.001
	PO4	6.18	2.67	7.94	3.47	−3.163	0.007
	O1	3.93	2.66	5.53	2.94	−4.095	0.001
	O2	4.55	2.67	5.99	3.18	−3.183	0.007
P3	Fz	−0.13	1.11	0.48	1.01	−2.679	0.019
	FCz	0.37	1.19	1.15	1.08	−2.385	0.033
	Cz	0.96	1.00	1.60	1.03	−2.033	0.063
	CPz	1.20	0.87	1.58	0.97	−1.451	0.170

But in the study of Handy et al. (2010), they found that dislike logos could elicit larger N2 than like logos, and disliked images had the capacity for quickly catching people's attention at an implicit level. In contrast to the experiment of Handy et al. (2010), participants were asked to click the mouse to pick out the product forms preferred or nonpreferred, which is a process of explicit evaluation during ERPs testing. So with more attention devoted to preferred product forms which could evoke positive feeling/emotion, enhance anterior N2 was evoked.

In previous studies, ERPs within the 200–400 ms window are associated with the perceptual aspects of visual evaluation (Handy et al., 2010; Li et al., 2015). Our study found that preferred smartphone forms elicited enhanced posterior P2 (peaking around 225 ms). Preference products can elicit positive feeling or emotion which is reflected in enhanced early ERP components for greater automatic arousal of positive stimuli (Van Strien et al., 2009). However, the valence effects are not consistent among previous studies (Feng et al., 2012). Tortosa et al. (2013) pointed out that P2 is larger for neutral than negative and positive stimuli. But in the study of Dennis and Chen (2007), enhanced posterior P2 is evoked by negative emotional stimuli. Feng et al. (2012) pointed out that valence and arousal play interactive role in the implicit processing of affective stimuli. While in our study, explicit evaluation of each stimulus is made, the type of paradigms and task/stimuli employed can influence the results (Tortosa et al., 2013). In consistent with the study of Handy et al. (2010), larger parietal/occipital P2 was also evoked by preferred smartphones in an explicit evaluation task.

From the results, preferred product forms elicited a larger and shorter frontocentral P3 than nonpreferred. P3 is thought to reflect the allocation of attention toward task-relevant and emotionally salient stimuli, and is called the more nebulous late positive component (Polich, 2007). As the preferred product forms could give participants good impression and grasp their attention, so larger P3 was evoked. Preferred product forms might have more attractive appearance to elicit larger P3/LPP, which was consistent

Table 2
Correlation coefficients for behaviour versus ERPs.

Indexes		Average amplitudes of ERPs(μv)			Latency of P3	Response time
		N2	P2	P3		
Average amplitudes of ERPs (μV)	N2	1				
	P2	−0.848** (p < 0.001)	1			
	P3	−0.444* (0.018)	0.367 (0.055)	1		
Latency of P3		0.090 (0.648)	−0.088 (0.656)	−0.016 (0.935)	1	
Response time		−0.113 (0.569)	0.182 (0.355)	−0.383* (0.044)	0.394* (0.038)	1

Note: $^{*}p < 0.05$, $^{**}p < 0.01$

with the results of Nittono (2013). But the result was not in line with Handy et al. (2010), the tasks whether required participants to evaluate the stimuli explicitly can lead to opposite results (Nosek, 2005). Moreover, preferred product forms elicited shorter latency than nonpreferred. Funada et al. (2002) pointed out that the latency of ERPs corresponds to subjects' preference, and shorter latencies were observed in preferred stimuli. From the perspective of emotion effect, pleasant/positive effect starts earlier than unpleasant/negative and reflects a preference toward pleasant pictures (Dolcos and Cabeza, 2002).

Third, the correlation between response time and ERPs showed that there was a negative correlation between response time and the amplitude of P3, but positive correlation between response time and the latency of P3. The amplitude of P3 is sensitive to the amount of attentional resources, and latency is related to the difficulty of object detection and judgment (Polich, 2007; Bledowski et al., 2004). Driven by the inner cognition, the psychology is reflected in faster response time. The behavioural results are confirmed by neural responses in our study. Preferred stimuli can evoke enhanced and shorter P3 (Funada et al., 2002; Dolcos and Cabeza, 2002) and faster response (Chen and Bargh, 1999; Bamford et al., 2015), and they are significantly correlated. Moreover, there were significant correlations between the amplitudes of N2 and P2, N2 and P3, and nearly significant correlation between P2 and P3, but between behavioural data and N2 or behavioural data and P2. The reasons maybe that P3/LPP is related to higher cognition (top-down cognition) (Tommaso et al., 2008) and driven by this, preferred or nonpreferred behaviour occurs. And P3 may affect down-top sensory information processing which is reflected in earlier visual ERPs peaks such as P2 and N2 (Crowley and Colrain, 2004).

5. Conclusion

In the present study, we investigate the neural responses correlated with user preference on product forms by ERPs. We are not the first to explore brain responses elicited by user preference with ERPs. Handy et al. (2010) studied a rapidly and implicitly evaluation of emotionally charged stimuli, and they pointed out that ERPs appears to be primarily driven by disliked logos. While in our study, an explicit evaluation of product forms are made, which guarantees that the psychological activities occurred during the EEG recording are elicited by preference judgment. In conclusion, enhanced N2, P2 and P3 were evoked by preferred product forms and shorter latency of P3 as well than nonpreferred. As the behavioural results showed, participants had faster response times for preferred product forms. The correlation between ERPs and behavioural results showed a consistent view, participants responded faster for preferred product forms, which was reflected in shorter latency and larger amplitude of P3.

There are limitations in this study. The participants are all from university with higher education, and other groups of participants need to be recruited. The research of different groups can help enterprises design special products depending on preference. Moreover, prices, brands and functional parameters are important factors affecting user's perception and should be considered.

All in all, this study sheds light on the ERPs in the gauging of user preference on product forms, not only enriches the methods of preference measurement, but also provides reference for product design. Further issues could be explored, such as which stimuli features foster evaluative judgments, other sensory channels should be considered to improve user experience of products. User cannot distinguish products unless making comparison among different products. So in our future research, comparison tasks, user experience interacting with smartphones, and what product features primarily drive user's perception will be taken into consideration.

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References

Agost, M.J., Vergara, M., 2014. Relationship between meanings, emotions, product preferences and personal values. application to ceramic tile floorings. Appl. Ergon. 45 (4), 1076–1086.
Alptekin, S.E., 2012. A fuzzy decision support system for digital camera selection based on user preferences. Expert Syst. Appl. 39 (3), 3037–3047.
Ariely, D., Berns, G.S., 2010. Neuromarketing: the hope and hype of neuroimaging in business. Nat. Rev. Neurosci. 11 (4), 284–292.
Bailenson, J.N., Pontikakis, E.D., Mauss, I.B., 2008. Real-time classification of evoked emotions using facial feature tracking and physiological responses. Int. J. Human Comput. Stud. 66 (5), 303–317.
Bamford, S., Broyd, S.J., Benikos, N., Ward, R., Wiersema, J.R., Sonuga-Barke, E., 2015. The late positive potential: a neural marker of the regulation of emotion-based approach-avoidance actions? Biol. Psychol. 105, 115–123.
Bhushan, V., Saha, G., Lindsen, J., Shimojo, S., Bhattacharya, J., 2012. How we choose one over another: predicting trial-by-trial preference decision. PLoS One 7 (8), 792–792.
Bledowski, C., Prvulovic, D., Goebel, R., Zanella, F.E., Linden, D.E., 2004. Attentional systems in target and distractor processing: a combined ERP and fMRI study. Neuroimage 22 (2), 530–540.
Borsci, S., Kuljis, J., Barnett, J., Pecchia, L., 2016. Beyond the user preferences: aligning the prototype design to the users' expectations. Hum. Factors Ergon. Manuf. Serv. Ind. 26 (1), 16–39.
Calvert, G.A., Brammer, M.J., 2012. Predicting consumer behavior: using novel mind-reading approaches. Pulse IEEE 3 (3), 38–41.
Carretié, L., Hinojosa, J.A., Martín-Loeches, M., Mercado, F., Tapia, M., 2004. Automatic attention to emotional stimuli: neural correlates. Hum. Brain Mapp. 22 (4), 290–299.
Céline, M.K., 2013. Neuroergonomics: a cognitive neuroscience approach to human factors and ergonomics. Ergonomics 57 (1), 137–138.
Chen, M., Bargh, J.A., 1999. Consequences of automatic evaluation: immediate behavioral predispositions to approach or avoid the stimulus. Personal. Soc. Psychol. Bull. 25 (2), 215–224.
Chuang, M.C., Chang, C.C., Hsu, S.H., 2001. Perceptual elements underlying user preferences toward product form of mobile phones. Int. J. Ind. Ergon. 27 (4), 247–258.
Crowley, K.E., Colrain, I.M., 2004. A review of the evidence for p2 being an independent component process: age, sleep and modality. Clin. Neurophysiol. 115 (4), 732–744.

Daliri, M.R., 2013. Kernel earth mover's distance for eeg classification. Clin. EEG Neurosci. 44 (3), 182–187.
Dennis, T.A., Chen, C.C., 2007. Neurophysiological mechanisms in the emotional modulation of attention: the interplay between threat sensitivity and attentional control. Biol. Psychol. 76 (1), 1–10.
Diego-Mas, J.A., Alcaide-Marzal, J., 2016. Single users' affective responses models for product form design. Int. J. Ind. Ergon. 53, 102–114.
Ding, Y., Guo, F., Zhang, X., Qu, Q., Liu, W., 2016. Using event related potentials to identify a user's behavioural intention aroused by product form design. Appl. Ergon. 55, 117–123.
Dolcos, F., Cabeza, R., 2002. Event-related potentials of emotional memory: encoding pleasant, unpleasant, and neutral pictures. Cogn. Affect. Behav. Neurosci. 2 (3), 252–263.
Fabiani, M., Gratton, G., Coles, M.G.H., 2000. Event related brain potentials: methods, theory and applications. In: Cacioppo, J.T., Tassinary, L.G., Berntson, G. (Eds.), Handbook of PsychoPhysiology. Cambridge University Press, NewYork, pp. 85–119.
Feng, C., Wang, L., Liu, C., Zhu, X., Dai, R., Mai, X., Luo, Y.J., 2012. The time course of the influence of valence and arousal on the implicit processing of affective pictures. PLoS One 7 (1), e29668. http://dx.doi.org/10.1371/journal.pone.0029668.
Funada, M.F., Shibukawa, M., Ninomija, S.P., 2002. Changes of event related potentials depend on the preference in pictures used for stimulations. In: Proceedings of the Second Joint EMBS/BMES Conference. Houston, TX, USA, pp. 23–26.
Guo, F., Ding, Y., Liu, W., Liu, C., Zhang, X., 2016. Can eye-tracking data be measured to assess product design?: visual attention mechanism should be considered. Int. J. Ind. Ergon. 53, 229–235.
Hampton, A.N., Adolphs, R., Tyszka, J.M., O'Doherty, J.P., 2007. Contributions of the amygdala to reward expectancy and choice signals in human prefrontal cortex. Neuron 55 (4), 545–555.
Handy, T.C., Smilek, D., Geiger, L., Liu, C., Schooler, J.W., 2010. ERP evidence for rapid hedonic evaluation of logos. J. Cogn. Neurosci. 22 (1), 124–138.
Herbert, C., Kissler, J., Junghöfer, M., Peyk, P., Rockstroh, B., 2006. Processing of emotional adjectives: evidence from startle EMG and ERPs. Psychophysiology 43 (2), 197–206.
Ho, C.H., Lu, Y.N., 2014. Can pupil size be measured to assess design products? Int. J. Ind. Ergon. 44 (3), 436–441.
Hsiao, S.W., Ko, Y.C., 2013. A study on bicycle appearance preference by using FCE and FAHP. Int. J. Ind. Ergon. 43 (4), 264–273.
Javor, A., Koller, M., Lee, N., Chamberlain, L., Ransmayr, G., 2013. Neuromarketing and consumer neuroscience: contributions to neurology. BMC Neurol. 13 (1), 1–12.
Kenning, P.H., Plassmann, H., 2008. How neuroscience can inform consumer research. Neural Syst. Rehabil. Eng. IEEE Trans. 16 (6), 532–538.
Khushaba, R.N., Wise, C., Kodagoda, S., Louviere, J., Kahn, B.E., Townsend, C., 2013. Consumer neuroscience: assessing the brain response to marketing stimuli using electroencephalogram (EEG) and eye tracking. Expert Syst. Appl. 40 (9), 3803–3812.
Lee, N., Broderick, A.J., Chamberlain, L., 2007. What is 'neuromarketing'? A discussion and agenda for future research. Int. J. Psychophysiol. 63 (2), 199–204.
Li, R., Qin, R., Zhang, J., Wu, J., Zhou, C., 2015. The esthetic preference of Chinese typefaces—an event-related potential study. Brain Res. 1598, 57–65.
Lin, Y.C., Lai, H.H., Yeh, C.H., 2007. Consumer-oriented product form design based on fuzzy logic: a case study of mobile phones. Int. J. Ind. Ergon. 37 (6), 531–543.
Lindsen, J.P., Jones, R., Shimojo, S., Bhattacharya, J., 2010. Neural components underlying subjective preferential decision making. Neuroimage 50 (4), 1626–1632.
Llinares, C., Page, A.F., 2011. Kano's model in kansei engineering to evaluate subjective real estate consumer preferences. Int. J. Ind. Ergon. 41 (3), 233–246.
Luck, S.J., 2014. An Introduction to the Event-related Potential Technique, 2nd Revised edition. The MIT Press, Cambridge, MA.
Ma, Q.G., Wang, K., Wang, X.Y., Wang, C.C., Wang, L., 2010. The influence of negative emotion on brand extension as reflected by the change of N2: a preliminary study. Neurosci. Lett. 485, 237–240.
McClure, S.M., Li, J., Tomlin, D., Cypert, K.S., Montague, L.M., Montague, P.R., 2004. Neural correlates of behavioral preference for culturally familiar drinks. Neuron 44 (2), 379–387.
Ming, C.C., Chang, C.C., Shang, H.H., 2001. Perceptual factors underlying user preferences toward product form of mobile phones. Int. J. Ind. Ergon. 27 (4), 247–258.
Morin, C., 2011. Neuromarketing: the new science of consumer behavior. Society 48 (2), 131–135.
Nittono, H., 2013. Late positive potentials associated with the attractiveness of the appearances of commercial goods. Clin. Neurophysiol. 124 (8), e35. http://dx.doi.org/10.1016/j.clinph.2013.02.098.
Norman, D.A., 2004. Emotional Design: Why We Love (or Hate) Everyday Things. Basic Books, New York.
Nosek, B.A., 2005. Moderators of the relationship between implicit and explicit evaluation. J. Exp. Psychol. General 134 (4), 565–584.
Ohira, H., Hirao, N., 2015. Analysis of skin conductance response during evaluation of preferences for cosmetic products. Front. Psychol. 6, 1031–1035.
Patel, S.H., Azzam, P.N., 2005. Characterization of N200 and P300: selected studies of the event-related potential. Int. J. Med. Sci. 2 (4), 147–154.
Plassmann, H., Ambler, T., Braeutigam, S., Kenning, P., 2007. What can advertisers learn from neuroscience? Int. J. Advert. 26 (2), 151–175.
Polich, J., 2007. Updating P300: an integrative theory of P3a and P3b. Clin. Neurophysiol. 118 (10), 2128–2148.
Righi, S., Orlando, V., Marzi, T., 2014. Attractiveness and affordance shape tools neural coding: insight from ERPs. Int. J. Psychophysiol. 91 (3), 240–253.
Shieh, M.D., Yang, C.C., 2008. Classification model for product form design using fuzzy support vector machines. Comput. Ind. Eng. 55 (1), 150–164.
Solnais, C., Andreu-Perez, J., Sánchez-Fernández, J., Andréu-Abela, J., 2013. The contribution of neuroscience to consumer research: a conceptual framework and empirical review. J. Econ. Psychol. 36 (6), 68–81.
Van Strien, J.W., Langeslag, S.J., Strekalova, N.J., Gootjes, L., Franken, I.H., 2009. Valence interacts with the early ERP old/new effect and arousal with the sustained ERP old/new effect for affective pictures. Brain Res. 1251 (C), 223–235.
Sylcott, B., Cagan, J., Tabibnia, G., 2013. Understanding consumer tradeoffs between form and function through metaconjoint and cognitive neuroscience analyses. J. Mech. Des. 135 (10), 257–264.
Tommaso, M., Pecoraro, C., Sardaro, M., Serpino, C., Lancioni, G., Livrea, P., 2008. Influence of aesthetic perception on visual event-related potentials. Conscious. Cogn. 17, 933–945.
Tortosa, M.I., Lupiáñez, J., Ruz, M., 2013. Race, emotion and trust: an ERP study. Brain Res. 1494 (4), 44–55.
Treleaven-Hassard, S., Gold, J., Bellman, S., Schweda, A., Ciorciari, J., Critchley, C., Varan, D., 2010. Using the P3a to gauge automatic attention to interactive television advertising. J. Econ. Psychol. 31 (5), 777–784.
Tsai, J.P., Ho, C.F., 2013. Does design matter? affordance perspective on smartphone usage. Ind. Manag. Data Syst. 113 (9), 1248–1269.
Van der Laan, L.N., De Ridder, D.T., Viergever, M.A., Smeets, P.A., 2012. Appearance matters: neural correlates of food choice and packaging aesthetics. PLoS One 7 (7), e41738. http://dx.doi.org/10.1371/journal.pone.00471738.
Vogel, E.K., Machizawa, M.G., 2004. Neural activity predicts individual differences in visual working memory capacity. Nature 428 (6984), 748–751.
Wang, Y.J., Minor, M.S., 2008. Validity, reliability, and applicability of psychophysiological techniques in marketing research. Psychol. Mark. 25 (2), 197–232.
Wang, X., Huang, Y., Ma, Q., Li, N., 2012. Event-related potential P2 correlates of implicit aesthetic experience. Neuroreport 23, 862–866.
Wu, W.Y., Liao, Y.K., Chatwuthikrai, A., 2014. Applying conjoint analysis to evaluate consumer preferences toward subcompact cars. Expert Syst. Appl. 41 (6), 2782–2792.
Yadav, H.C., Jain, R., Shukla, S., Avikal, S., Mishra, P.K., 2013. Prioritization of aesthetic attributes of car profile. Int. J. Ind. Ergon. 43 (4), 296–303.
Yuan, J., Zhang, Q., Chen, A., Li, H., Wang, Q., Zhuang, Z., Jia, S., 2007. Are we sensitive to valence differences in emotionally negative stimuli? Electrophysiological evidence from an ERP study. Neuropsychologia 45 (12), 2764–2771.
Yun, M.H., Han, S.H., Sang, W.H.J.K., 2003. Incorporating user satisfaction into the look-and-feel of mobile phone design. Ergonomics 46 (13–14), 1423–1440.